Highlights

Financial Resources for Academic R&D

- ♦ **In 2000, U.S. academic institutions spent an estimated $30 billion (in current dollars) on research and development (R&D).** The Federal Government provided $17.5 billion, academic institutions $6.0 billion, state and local governments $2.2 billion, industry $2.3 billion, and other sources $2.2 billion.
- ♦ **Over the past half century (between 1953 and 2000), average annual growth in R&D has been stronger for the academic sector than for any other R&D-performing sector.** During this period, academic R&D rose from 0.07 to 0.30 percent of the gross domestic product, more than a fourfold increase. Industrially performed R&D has grown more rapidly in recent years than R&D performed in any other sector.
- ♦ **The academic sector, which performs 43 percent of basic research, continues to be the largest performer of basic research in the United States.** Academic R&D activities have been highly concentrated at the basic research end of the R&D spectrum since the late 1950s. In 2000, an estimated 69 percent of academic R&D expenditures went for basic research, 24 percent for applied research, and 7 percent for development.
- ♦ **The Federal Government continues to provide the majority of funds for academic R&D, although its share has been declining steadily since 1966.** The Federal Government provided an estimated 58 percent of the funding for R&D performed in academic institutions in 2000, down from its peak of 73 percent in the mid-1960s.
- ♦ **After the Federal Government, academic institutions performing R&D provided the second largest share of academic R&D support.** Except for a brief downturn in the first half of the 1990s, the institutional share of academic R&D support has been increasing steadily since the early 1960s, reaching an estimated 20 percent in 2000. Some of the funds directed to research activities by institutions come from Federal, state, or local government sources but are classified as institutional funds because they are not restricted to research and the universities decide how to use them.
- ♦ **Industrial R&D support to academic institutions has grown more rapidly (albeit from a small base) than support from all other sources during the past quarter century.** Industry's share was an estimated 7.7 percent in 2000, its highest level since the 1950s. However, industrial support still accounts for one of the smallest shares of academic R&D funding.
- ♦ **Three agencies are responsible for more than four-fifths of Federal obligations for academic R&D: the National Institutes of Health (NIH) for 60 percent, the National Science Foundation (NSF) for 15 percent, and the Department of Defense for 9 percent.** Federal agencies emphasize different science and engineering (S&E) fields in their funding of academic research, with some, such as NIH, concentrating their funding in one field and others, such as NSF, having more diversified funding patterns.
- ♦ **After increasing steadily between the early 1970s and early 1990s, the number of universities and colleges receiving Federal R&D support began to decline after 1994.** Almost the entire increase during that period, and the recent decrease, occurred among institutions other than those classified by the Carnegie Foundation for the Advancement of Teaching as research and doctorate-granting institutions. Of these institutions, 559 received Federal R&D support in 1999 compared with 676 in 1994, 461 in 1980, and 341 in 1971.
- ♦ **The R&D emphasis of the academic sector, as measured by its S&E field shares, changed between 1973 and 1999, with absolute shares increasing for life sciences, engineering, and computer sciences and declining for social sciences, psychology, environmental (earth, atmospheric, and ocean) sciences, and physical sciences.** In 1999, life sciences accounted for 57 percent of total academic R&D expenditures, 56 percent of Federal academic R&D expenditures, and 58 percent of non-Federal academic R&D expenditures.
- ♦ **The distribution of Federal and non-Federal funding of academic R&D varies by field.** In 1999, the Federal Government supported more than three-quarters of academic R&D expenditures in both physics and atmospheric sciences but one-third or less of the R&D in economics, political science, and agricultural sciences.
- ♦ **Total academic space for S&E research increased by almost 35 percent between 1988 and 1999, up from about 112 million to 151 million net assignable square feet.** When completed, construction projects initiated between 1986 and 1999 are expected to produce more than 72 million square feet of new research space, which will either replace obsolete or inadequate space or be added to existing space.
- ♦ **R&D equipment intensity—the percentage of total annual R&D expenditures from current funds devoted to research equipment—has declined dramatically during the past 15 years.** After reaching a high of 7 percent in 1986, R&D equipment intensity declined to 5 percent in 1999.

Doctoral Scientists and Engineers in Academia

- **An estimated 28 percent of doctoral scientists and engineers at U.S. universities and colleges in 1999 were foreign born.** Computer sciences and engineering had the highest percentages (37 and 35 percent, respectively); followed by mathematics (28 percent); physical, life, and social sciences (from 23 to 19 percent); and psychology (8 percent). Many of these scientists and engineers had obtained their doctorates from U.S. institutions. These estimates are conservative and do not reflect the strong rise in immigration during the 1990s.
- **University hiring of young faculty is picking up, but full-time faculty appointments are less available than ever.** Those entering academia with recently earned doctorates are more likely to receive postdoctoral (43 percent) than faculty positions (39 percent). Only half of those with a doctorate earned four to seven years earlier are in tenure track positions, well below the experience of previous decades.
- **Among new hires, the percentage of white males has been cut in half, from 80 percent in 1973 to 40 percent in 1999,** reflecting a declining propensity to earn a S&E doctorate and the relative attractiveness of nonacademic employment. Growth occurred in the hiring of women and young doctorate-holders from minority backgrounds.
- **An academic researcher pool outside the regular faculty ranks has grown over the years.** The faculty share of the academic workforce has declined, as more research activity is being carried out by postdoctorates and others in full-time nonfaculty positions. This change toward nonfaculty research effort was pronounced in the 1990s. A long-term upward trend shows those with primary research activity increasing relative to total employment.
- **Graduate students play a key role in U.S. academic S&E research, and research assistantships were the primary means of support for about one-quarter of them.** The number of research assistants has risen faster than overall graduate enrollment. A shift is evident away from the physical and into the life sciences, reflecting changes in the field distribution of academic research funds.
- **The percentage of academic researchers with Federal support for their work was lower in 1999 than in the late 1980s.** Exceptions were engineering; computer sciences; and earth, atmospheric, and ocean sciences. Full-time faculty were less frequently supported than other full-time employees, especially postdoctorates, 80 percent of whom received Federal funds. Young Ph.D.-holders in full-time faculty positions reported sharply lower rates of Federal support than their counterparts in other positions.
- **In the view of academic researchers, no large shift has taken place during the 1990s in the nature of academic R&D.** Of those with research as their primary work activity, a modestly larger percentage reported applied and development work in 1999 than in 1993. Among all academic researchers, no such effect was evident.

Outputs of Scientific and Engineering Research: Articles and Patents

- **In 1999, authors from around the world published approximately 530,000 articles in a set of refereed journals included in the Science Citation Index since 1985.** This represented an average increase of 1 percent per annum from the prior decade, with very disparate growth patterns by region. Authors from Western Europe, Asia, and Latin America achieved strong growth in papers; authors from the United States, Eastern Europe, and Sub-Saharan Africa showed a decline of articles in absolute terms.
- **The number of U.S.-authored papers (approximately 164,000 articles in 1999) appear to have fallen from the level in the early 1990s.** This phenomenon is not exclusive to the United States; output fell in the United Kingdom, Canada, and the Netherlands during the latter half of the 1990s. The trend in the United States affected all fields of science, except earth and space science, and most sectors. Although the U.S. share of world output has been in a long-term decline due to strong growth in other countries, the absolute U.S. output volume had grown consistently over the prior three decades.
- **The U.S. portfolio of scientific papers is broad and diverse, although it is dominated by life sciences, particularly biomedical research and clinical medicine.** Social and behavioral sciences also are an important component in the U.S. portfolio. As a region, Western Europe has a similar life-science dominated portfolio, but for major European nations the physical sciences shares are larger than in the U.S. A portfolio consisting of physical sciences and engineering is much more prominent for countries in Eastern Europe, Asia, and Latin America.
- **Scientific collaboration between institutions has increased significantly over the past two decades as a result of IT, the growing complexity and scale of scientific research, and economic and political factors.** In the United States, more than half of all articles in 1999 had authors from multiple institutions, primarily due to a significant rise in international collaboration. By 1999, 1 article in 5 had one non-U.S. author compared with 1 article in 10 in the 1980s.

- **The U.S. has the largest share of internationally authored papers, although this share has declined as other countries have increased and expanded their ties with other countries.** U.S. authors partnered with authors from 160 countries in 1999, and those countries ranged from mature scientific producers of OECD to developing countries. Countries with authors with high levels of collaboration included Western European countries, Japan, Russia, and the newly industrialized economies in Asia. Collaboration also increased in other regions, both intraregionally and with other regions, especially the United States, Western Europe, and Asia.

- **In the United States, collaboration between institutions is extensive, accounting for at least 77 percent of multiple-authored papers by all institutions except academia.** Academia is the center of cross-sector collaboration and plays a key role in the life sciences and chemistry fields. Other distinct partnerships include the private sector in life sciences, chemistry, earth and space sciences, and the Federal Government in earth and space science, and physics.

- **The pattern of research cited by scientific papers is underscored by the prominence of U.S. and Western Europe research cited adjusted for their world share of literature.** The United States is the most highly cited on a regional basis and is prominent in the fields of clinical medicine, biomedical research, chemistry, earth and space science, and social and behavioral sciences. Several Western European countries, notably Switzerland, the Nordic countries, Denmark, and the Netherlands, also are highly cited based on their world share of literature.

- **Developing and emerging countries are cited with less frequency than mature science producers are, but several countries are highly cited in specific fields.** In addition, the citation of Latin American literature, adjusted for its world share of literature, has risen markedly. The United States and Western Europe are the most prominently cited by developing regions, but Latin America and sub-Saharan Africa cite each other's literature at a fairly high degree.

- **Academic patenting has continued to increase and now accounts for 5 percent of all U.S.-owned patents.** Academic patenting is more heavily concentrated in particular application areas than U.S. patenting in general, with especially heavy weight on life sciences applications.

- **Universities are increasingly taking equity positions in spinoff companies as a way of capitalizing on their intellectual property.** The number of equity licenses and options executed grew from 99 in 1995 to 272 in 1998 and 243 in 1999. The total number of new licenses and options reached almost 3,300. Gross royalties in 1999 were $641 million, more than double the 1995 amount.

- **The increase in citations of U.S. patents to research suggests the growing importance of science in practical application of technology.** Over the past two decades, the research citations of U.S. patents rose more than 10-fold, largely because of increases in the life sciences. Citations to most other fields also increased, but at a much lower rate.

- **U.S. literature is the most highly cited (on the basis of relative U.S. share of literature) in U.S. patents by both domestic and foreign inventors.** Asian literature in engineering and technology and physics also is prominently cited by Western European and U.S. inventors, respectively.

Introduction

Chapter Background

A strong national consensus supports the public funding of academic research, and although the Federal Government plays a diminishing role, it still provides close to 60 percent of the financial resources. More than half of academic research and development (R&D) funds go to the life sciences, and this share increased during the past quarter century, raising concern about whether the distribution of funds is appropriately balanced. The number of academic institutions receiving Federal support for R&D activities increased dramatically during the past several decades, expanding the base of the academic R&D enterprise. Recently, however, this number began to decline. The Federal Government plays a minor role in providing direct support to universities and colleges for construction of their research facilities. Nevertheless, the amount of academic science and engineering (S&E) research space grew continuously over the past decade. In contrast, the Federal Government accounted for almost 60 percent of direct expenditures of current funds for academic research equipment, but the percentage of total annual R&D expenditures devoted to such equipment declined noticeably during the past decade. Doctoral S&E faculty in universities and colleges play a critical role in ensuring an adequate, diverse, and well-trained supply of S&E personnel for all sectors of the economy. Until recently, positive outcomes and impacts of R&D were taken for granted; however, the system has begun to face demands that it devise means and measures to account for specific Federal R&D investments.

This chapter addresses key issues of the academic R&D enterprise, such as the importance of a Federal role in supporting academic research; the appropriate balance of funding across S&E disciplines; the breadth and strength of the academic base of the nation's S&E and R&D enterprise; the adequacy of research facilities and instrumentation at universities and colleges; the role of doctoral S&E faculty, including both their teaching and their research responsibilities; and accountability requirements, including measuring outputs and larger social outcomes.

Chapter Organization

The first section of this chapter discusses trends in the financial resources provided for academic R&D, including allocations across both academic institutions and S&E fields. Because the Federal Government has been the primary source of support for academic R&D for more than half a century, the importance of selected agencies in supporting individual fields is explored in detail. This section also presents data on changes in the number of academic institutions that receive Federal R&D support and then examines the status of two key elements of university research activities: facilities and instrumentation.

The next section discusses trends in the employment of academic doctoral scientists and engineers and examines their activities and demographic characteristics. The discussion of employment trends focuses on full-time faculty, postdoctorates, graduate students, and other positions. Differences between the nation's largest research universities and other academic institutions are considered, as are shifts in the faculty age structure. The involvement of women and underrepresented minorities, including Asians/Pacific Islanders, is also examined. Attention is given to participation in research by academic doctoral scientists and engineers, the relative balance between teaching and research, and Federal support for research. Selected demographic characteristics of recent doctorate-holders entering academic employment are reviewed.

The chapter concludes with an assessment of two research outputs: scientific and technical articles in a set of journals covered by the Science Citation Index (SCI) and the Social Science Citation Index (SSCI) and patents issued to U.S. universities. (A third major output of academic R&D, educated and trained personnel, is discussed in the preceding section of this chapter and in chapter 2). This section looks specifically at the volume of research (article counts), collaboration in the conduct of research (joint authorship), use in subsequent scientific activity (citation patterns), and use beyond science (citations to the literature on patent applications). It concludes with a discussion of academic patenting and some returns to academic institutions from their patents and licenses.

Financial Resources for Academic R&D

Academic R&D is a significant part of the national R&D enterprise.[1] Enabling U.S. academic researchers to carry out world-class research requires adequate financial support as well as excellent research facilities and high-quality research equipment. Consequently, assessing how well the academic R&D sector is doing, the challenges it faces, and how it is responding to those challenges requires data and information on a number of important issues relating to the financing of academic R&D, including:

- the level and stability of overall funding,
- the sources of funding and changes in their relative importance,
- the distribution of funding among the different R&D activities (basic research, applied research, and development),
- the balance of funding among S&E fields and subfields (or fine fields),
- the distribution of funding among various types of academic R&D performers and the extent of their participation,

[1] Federally funded research and development centers (FFRDCs) associated with universities are tallied separately and are examined in greater detail in chapter 4. FFRDCs and other national laboratories (including Federal intramural laboratories) also play an important role in academic research and education, providing research opportunities for both students and faculty at academic institutions.